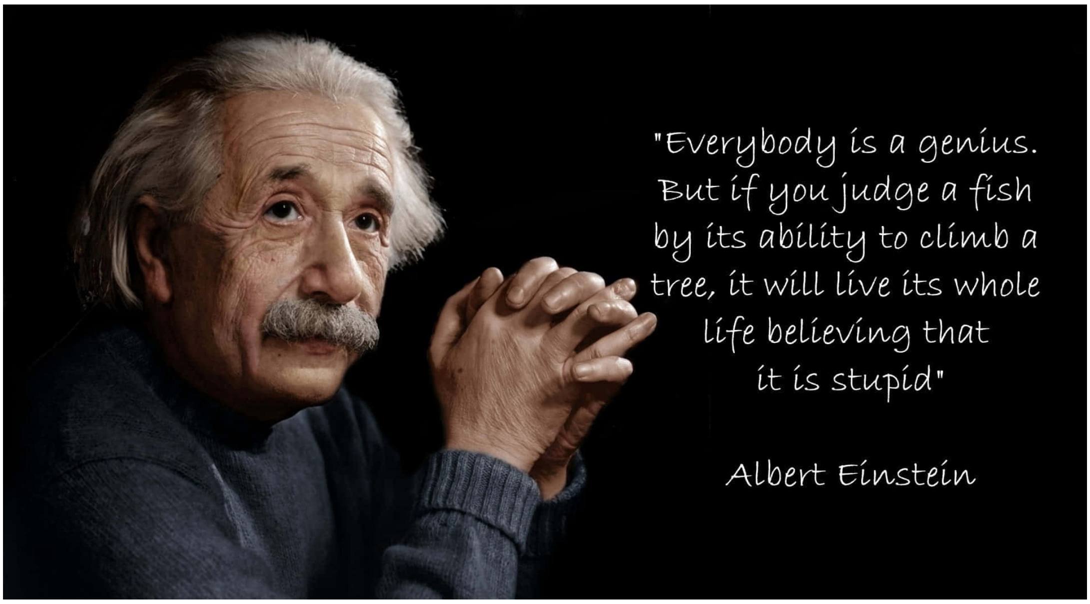
108
Greatest Of All Times

GOAT

Globally selected Personalities



14 Mar 1879 <::><::><::> 18 Apl 1955

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14 Mar 1879

18 Apl 1955

Brain of the 20th Century

Albert Einstein

The Nobel Prize in Physics 1921

Affiliation at the time of the award:
Kaiser-Wilhelm-Institut (now Max-Planck-Institut) für Physik, Berlin, Germany

Prize motivation:
"for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect"

Albert Einstein received his Nobel Prize one year later, in 1922.
Prize share: 1/1

https://www.nobelprize.org/prizes/physics/1921/einstein/biographical/

Albert Einstein

Albert Einstein was born at Ulm, in Württemberg, Germany, on March 14, 1879. Six weeks later the family moved to Munich, where he later on began his schooling at the Luitpold Gymnasium. Later, they moved to Italy and Albert continued his education at Aarau, Switzerland and in 1896 he entered the Swiss Federal Polytechnic School in Zurich to be trained as a teacher in physics and mathematics. In 1901, the year he gained his diploma, he acquired Swiss citizenship and, as he was unable to find a teaching post, he accepted a position as technical assistant in the Swiss Patent Office. In 1905 he obtained his doctor's degree.

During his stay at the Patent Office, and in his spare time, he produced much of his remarkable work and in 1908 he was appointed Privatdozent in Berne. In 1909 he became Professor Extraordinary at Zurich, in 1911 Professor of Theoretical Physics at Prague, returning to Zurich in the following year to fill a similar post. In 1914 he was appointed Director of the Kaiser Wilhelm Physical Institute and Professor in the University of Berlin. He became a German citizen in 1914 and remained in Berlin until 1933 when he renounced his citizenship for political reasons and emigrated to America to take the position of Professor of Theoretical Physics at Princeton. He became a United States citizen in 1940 and retired from his post in 1945.

After World War II, Einstein was a leading figure in the World Government Movement, he was offered the Presidency of the State of Israel, which he declined, and he collaborated with Dr. Chaim Weizmann in establishing the Hebrew University of Jerusalem.

Einstein always appeared to have a clear view of the problems of physics and the determination to solve them. He had a strategy of his own and was able to visualize the main stages on the way to his goal. He regarded his major achievements as mere stepping-stones for the next advance.

At the start of his scientific work, Einstein realized the inadequacies of Newtonian mechanics and his special theory of relativity stemmed from an attempt to reconcile the laws of mechanics with the laws of the electromagnetic field. He dealt with classical problems of statistical mechanics and problems in which they were merged with quantum theory: this led to an explanation of the Brownian movement of molecules.

He investigated the thermal properties of light with a low radiation density and his observations laid the foundation of the photon theory of light.

In his early days in Berlin, Einstein postulated that the correct interpretation of the special theory of relativity must also furnish a theory of gravitation and in 1916 he published his paper on the general theory of relativity. During this time, he also contributed to the problems of the theory of radiation and statistical mechanics.

In the 1920s, Einstein embarked on the construction of unified field theories, although he continued to work on the probabilistic interpretation of quantum theory, and he persevered with this work in America. He contributed to statistical mechanics by his development of the quantum theory of a monatomic gas and he has also accomplished valuable work in connection with atomic transition probabilities and relativistic cosmology.

After his retirement he continued to work towards the unification of the basic concepts of physics, taking the opposite approach, geometrisation, to the majority of physicists.

Einstein's researches are, of course, well chronicled and his more important works include *Special Theory of Relativity* (1905), *Relativity* (English translations, 1920 and 1950), *General Theory of Relativity* (1916), *Investigations on Theory of Brownian Movement* (1926), and *The Evolution of Physics* (1938). Among his non-scientific works, *About Zionism* (1930), *Why War?* (1933), *My Philosophy* (1934), and *Out of My Later Years* (1950) are perhaps the most important.

Albert Einstein received honorary doctorate degrees in science, medicine and philosophy from many European and American universities. During the 1920's he lectured in Europe, America and the Far East, and he was awarded Fellowships or Memberships of all the leading scientific academies throughout the world. He gained numerous awards in recognition of his work, including the Copley Medal of the Royal Society of London in 1925, and the Franklin Medal of the Franklin Institute in 1935.

Einstein's gifts inevitably resulted in his dwelling much in intellectual solitude and, for relaxation, music played an important part in his life. He

married Mileva Maric in 1903 and they had a daughter and two sons; their marriage was dissolved in 1919 and in the same year he married his cousin, Elsa Löwenthal, who died in 1936. He died on April 18, 1955 at Princeton, New Jersey.

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Nominations to Nobel Prize

Nominated on 62 occasions for the Nobel Prize in

- Physics 1910, by Wilhelm Ostwald
- Physics 1912, by Clemns Schaefer
- Physics 1912, by Wilhelm Wien
- Physics 1913, by Bernhard Naunyn
- Physics 1913, by Wilhelm Ostwald
- Physics 1913, by Wilhelm Wien
- Physics 1914, by Orest Khvol´son
- Physics 1914, by Bernhard Naunyn
- Physics 1916, by Felix Ehrenhaft
- Physics 1917, by Arthur Haas
- Physics 1917, by Emil Warburg
- Physics 1917, by Pierre Weiss
- Physics 1918, by Stefan Meyer
- Physics 1918, by Felix Ehrenhaft
- Physics 1918, by Max von Laue
- Physics 1918, by Edgar Meyer
- Physics 1918, by Emil Warburg
- Physics 1918, by Wilhelm Wien
- Physics 1919, by Svante Arrhenius
- Physics 1919, by Max von Laue
- Physics 1919, by Edgar Meyer
- Physics 1919, by Max Planck
- Physics 1919, by Emil Warburg
- Physics 1920, by Niels Bohr
- Physics 1920, by Wilhelm Julius
- Physics 1920, by Heike Kamerlingh Onnes
- Physics 1920, by Hendrik Lorentz
- Physics 1920, by Leonard Ornstein
- Physics 1920, by Wilhelm von Waldeyer-Hartz
- Physics 1920, by Emil Warburg

- Physics 1920, by Pieter Zeeman
- Physics 1921, by Carl Charlier
- Physics 1921, by Hans Dällenbach
- Physics 1921, by Sir Arthur Eddington
- Physics 1921, by Arthur Haas
- Physics 1921, by Jacques Hadamard
- Physics 1921, by George Jaffé
- Physics 1921, by Theodore Lyman
- Physics 1921, by Erich Marx
- Physics 1921, by Gunnar Nordström
- Physics 1921, by Carl Oseen
- Physics 1921, by Max Planck
- Physics 1921, by Charles Walcott
- Physics 1921, by Emil Warburg
- Physics 1921, by Otto Wiener
- Physics 1922, by Max von Laue
- Physics 1922, by Stefan Meyer
- Physics 1922, by Max Planck
- Physics 1922, by Marcel Brillouin
- Physics 1922, by Théophile de Donder
- Physics 1922, by Felix Ehrenhaft
- Physics 1922, by Robert Emden
- Physics 1922, by Jacques Hadamard
- Physics 1922, by Paul Langevin
- Physics 1922, by Edgar Meyer
- Physics 1922, by Bernhard Naunyn
- Physics 1922, by Gunnar Nordström
- Physics 1922, by Carl Oseen
- Physics 1922, by Edward Poulton
- Physics 1922, by Arnold Sommerfeld
- Physics 1922, by Ernst Wagner
- Physics 1922, by Emil Warburg

Submitted 9 nominations, for the Nobel Prize in

- Physics 1919, nominee: Max Planck
- Physics 1924, nominee: James Franck, Gustav Hertz
- Physics 1926, nominee: Arthur Compton
- Physics 1932, nominee: Werner Heisenberg, Erwin Schrödinger
- Physics 1933, nominee: Erwin Schrödinger
- Physics 1940, nominee: Otto Stern, Isidor Rabi
- Physics 1945, nominee: Wolfgang Pauli

- Physics 1954, nominee: Walther Bothe
- Chemistry 1929, nominee: Carl Bosch

Explore a visualization of the nominations

Search for nominees and nominators in the Nomination Archive

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This autographed photo of Albert Einstein with his tongue out was sold at auction for $125,000.

TIMELINE

Given Albert Einstein's intense and diverse private, professional and social life, no chronology of his life can be reduced to a few notes on key events: his fame and importance meant that everything he did and everything that happened to him was significant. Nonetheless, the following timeline is meant to summarise some of the most important events:

1879	Born on 14 March in Ulm, Germany
1880	Se traslada con su familia a Munich
1885-88	Attends a Catholic school
1889-94	Student at the Luitpold Gymnasium (now the Albert Einstein Gymnasium)
1894	His family moves to Milan. Einstein leaves the Institute without completing his studies and goes to Pavia, where he lives with his family
1895-96	He attends the cantonal school of Aarau, Switzerland
1896	He renounces his German citizenship. Admitted to the Polytechnic School in Zurich, where he completes his studies in 1900
1901	Obtains Swiss nationality
1902	Employed at the Swiss patent office in Berne
1903	Marries Mileva Maric
1904	His son Hans Albert is born
1905	Annus mirabilis. Receives a PhD from the University of Zurich
1909	Leaves his job in the patent office. Obtains a post as associate lecturer in Theoretical Physics at the University of Zurich

1910	Son Eduard is born
1911-12	Lecturer in Theoretical Physics at the University of Prague
1912-14	Lecturer in Theoretical Physics at the Federal Technological Institute of Zurich (formerly the Polytechnic)
1914	Lecturer at the University of Berlin and member of the Prussian Academy of Sciences. Mileva and the children stay in Zurich
1915	Begins publications on the general theory of relativity
1917	Director of the Kaiser Wilhelm Institute of Physics in Berlin
1917-20	Einstein's health deteriorates. He is looked after by his cousin, Elsa Loewenthal
1919	Divorces Mileva and marries Elsa. Solar eclipse confirms Einstein's predictions on the deflection of light rays. Remarkable jump to world fame
1921	Visits US for first time with Chaim Weizmann
1922	Awarded 1921 Nobel prize for Physics.Publishes his first work on the unified field theory. Becomes member of the League of Nations' Committee on Intellectual Co-operation. Begins a tour of Europe, Asia, the Middle East, South America and the United States
1927	First debates with Niels Bohr on quantum mechanics
1928	Diagnosed with a heart condition
1932	Hitler, born in Austria, is granted German citizenship. He takes power in Germany and Nazi anti-Semitism intensifies
1933	Einstein and his family flee to Princeton, USA

1936 Elsa dies

1939 Outbreak of World War II. Einstein signs letter to President Roosevelt warning of the threat to the world of Germany's manufacturing an atom bomb

1940 Takes American citizenship

1944 Re-writes the 1905 manuscript on the special theory of relativity which is auctioned for six million dollars to aid the allied cause

1945 Atom bombs dropped on Hiroshima and Nagasaki

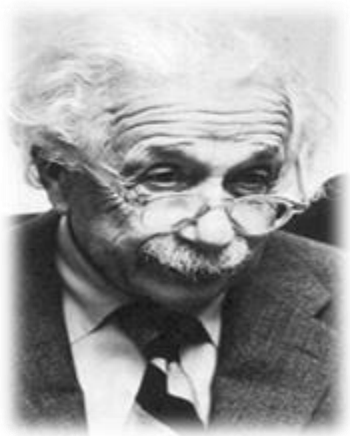
1946 Chairs the Emergency Committee of Atomic Scientists. Continues his campaign against re-armament and in favour of a world government

1947 Mileva Maric dies in Zurich

1950 Appoints Otto Nathan and Helen Dukas as his executors

1952 Offered and declines the presidency of the state of Israel

1955 With Bertrand Russell, draws up a manifesto against the nuclear threat. On 18 April, Einstein dies at Princeton hospital as the result of a burst aortic aneurysm in the abdominal aorta. He was cremated and his ashes scattered into the Delaware River



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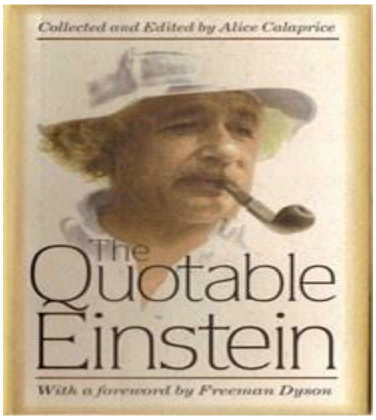
Quotes

Texts by Dr Antonio Moreno González



Most publications on Einstein and his work are filled with quotes by and about him. The reliability of everything that has been published is at the very least questionable. The publication of his complete works, The Collected Papers of Albert Einstein , begun in 1976 under the supervision of John Stachel, offers a faithful look at a figure who for different reasons has been misinterpreted by different authors. One of the most reliable collections of quotations is Alice Calaprice's The Quotable Einstein (Princeton University Press, 1996), and the biographies written by those who worked with him or formed part of his closest circles. All the quotations given on the following pages have been taken from these sources.

[A] Einstein said ...

"It was formerly believed that if all material things disappeared out of the universe, time and space would be left. According to the relativity theory, however, time and space would disappear together with the things".

"Do you talk about anything other than physics?", a reporter asked Einstein at a press conference. To which Einstein replied: "Yes, but not to you".

"We want to be given less praise but to be read with greater application". Einstein appropriated this phrase which he attributed to a "poet" in the speech he delivered to the Real Academia de Ciencias Exactas, Físicas y Naturales in Spain in 1923.

"Put your hand on a hot stove for a minute, and it seems like an hour. Sit with a pretty girl for an hour, and it seems like a minute. THAT'S relativity."

"I wonder about my attitude to life. I prefer giving to receiving, under any circumstance; I do not place importance on my person, nor the accumulation of wealth; I am not ashamed of my weaknesses, or of my errors and I instinctively take things with good humour and equanimity. There are many people like me and I do not understand at all why I have been turned into some sort of idol. It is without doubt, as incomprehensible as the mystery of an avalanche, which can be triggered by a single grain of dust, and which takes a given path".

"As far as the theorems of mathematics refer to reality, they are not certain, and as far as they are certain, they do not refer to reality".

[B] They said about him ...

"Following confirmation of his general theory of relativity in 1919, Einstein became a national asset for German science, badly hit by the Great War and the political, social and academic tensions that had arisen in the country, [...] the man best able to help restore the reputation of German science in hostile foreign countries" (Fried Stern, Einstein's German World , 60)

Niels Bohr, after recounting his discussions- sometimes heated- with Einstein, who was radically opposed to the quantum uncertainty, wrote: "I hope, however, to have given a fair impression of how much it meant for me to profit from the inspiration we all obtain from any contact with Einstein" (Niels Bohr, Atomic physics and Human Knowledge , 82).

"EINSTEIN, the magician physicist of the sad, rounded face, in his innocent and unconscious moral halo of white curls-- the most pathetic face of today's world, even when he sticks his tongue out at reporters--repeats, to any one who wants to or has to or can hear him, that he can only be human in abstract, but can never unite in any way with anything individually human, not even with the most familiar or intimate" (Juan Ramón Jiménez, La corriente infinita , 265). "I have on my desk a book by Einstein that confirms my thesis. The book is called The World As I See It. It is a series of opinions about everything, and these opinions are utterly, utterly worthless. My concierge says things which are just as valuable, when he starts giving forth about the human and the divine. Mr. Einstein is probably a great physicist, though I won't make any such claim, because I do not consider myself enough of an expert on physics to give an opinion that is worth anything. But such a consideration does not halt the physicist's pen. While we men of moral and political science are hold physics in deep respect, physicists, on the other hand, move into our territory with the same liberty as if it were their own, and emerge with some simplistic remarks that would make anyone laugh" ("El bueno de Einstein", Obras , Ramiro de Maeztu, 236).

" In the petals of a rose
stands the formula:
$E = mc^2$

I shall refuse to look away.
I shall refuse to let
my eyes
be crushed by the asphalt.

And God knows
I love the city"
("Ciudad", Libro de Alineaciones , Clara Janés)

"Before my window passes a man dressed with a blue jersey and flannel trousers, his hair tangled by the wind (two beautiful white locks in brilliant disorder)... He walks past every day at eleven o'clock. If it is cold, he wears a black coat. His hair tells me the direction of the wind, and his gaze makes my little daughter run and hide. What is he thinking about? From that brain came the equation that began to change the world. The equation looks new to me every time I see it: E = mc 2 ...nobody has ever said so much with so few signs" (Lettres sur la bombe atomique , Denis de Rougemont)

They cheer me because they all understand me, and they cheer you because no one understands you", Charlie Chaplin to Einstein.

[C] Einstein speaks about ...

During one of his radio talks

[1] The goals of human existence:
http://www.albert-einstein.org/

[2] His famous formula:
https://history.aip.org/exhibits/einstein/voice1.htm

[3] The fate of European Jews:
https://history.aip.org/exhibits/einstein/voice2.htm

[4] World peace:
https://history.aip.org/exhibits/einstein/voice3.htm

https://dipc.ehu.eus/en/science-society/albert-einstein/the-man/quotes-and-voices

"It is an irony of fate that I myself have been the recipient of excessive admiration and reverence from my fellow-beings, through no fault and no merit of my own."

‹‹‹ Albert Einstein, ca. 1930

Albert Einstein's Brain

https://www.ndtv.com/feature/einsteins-brain-was-stolen-cut-into-240-pieces-read-the-strange-story-5267181

Albert Einstein's brain was stolen by Thomas Harvey, a pathologist, who wanted to decode the secret behind the physicist's intelligence.

https://www.britannica.com/story/the-bizarre-posthumous-journey-of-einsteins-brain

Albert Einstein, touted as one of the greatest thinkers of the 20th century, died April 18, 1955, as a result of a fatal aneurysm, in Princeton, New Jersey. Despite Einstein's wishes to have his entire body cremated, the doctor who conducted his autopsy, Thomas Harvey, had other plans—he kept the brain aside. After this was discovered by Einstein's son Hans Albert, Dr Harvey convinced Hans Albert to allow him to keep the brain in order to investigate potential biological causes for Einstein's brilliance. Thus, a pathologist, with no particular neuroscience experience, came to be in possession of the highly coveted brain. This was just the beginning of the brain's strange adventure.

New York World-Telegram
The Sun
ALL Sports FINAL
NEW YORK, MONDAY, APRIL 18, 1955.
FIVE CENTS

DR. EINSTEIN IS DEAD AT 76

Kindergarten Tots to Get Free Vaccine
City Adds $4,000 To First Program

Baseball

Results at Jamaica

Reds Blasted As Bandung Talks Begin
Free Vietnam, Iraq Open Fire

Burst Artery Proves Fatal To Physicist
Father of Atom Age Passes at Princeton

Giants Crush Pirates

Shortly after claiming Einstein's brain, Dr Harvey lost his job at Princeton Hospital, where he had ostensibly intended to conduct his research. From Princeton, with Einstein's brain in tow, Harvey travelled to Philadelphia and around the Midwest, including Kansas and Missouri. Periodically, he would send or give sections of the brain to scientists to study, but for the most part the brain was kept hidden from the world in jars in his basement. However, despite repeated promises from Harvey, no studies were published on Einstein's brain until 1985, 30 years after Einstein's death, when a neuroscientist from UCLA, who had received sections from Harvey, published the first.

In the 1990s Harvey found himself back in Princeton, where he donated the remaining portion of the brain to a pathologist at the University Medical Center of Princeton (formerly Princeton Hospital) at Plainsboro, New Jersey. Over the course of 40 years, the brain had travelled across the United States, and pieces had been shipped overseas, but now it's back in the very same hospital where Einstein died over 50 years ago. Although Harvey kept much of the brain himself and over the years many scientists or their families returned the pieces they had, Einstein's brain has not quite finished its journey. It is likely that some pieces are still hidden away as family keepsakes, and some pieces are on display in the Mütter Museum in Philadelphia.

Harvey's purported goal in spiriting away the brain was to illuminate any potential biological differences between the brain of a genius such as Einstein and the brains of laypeople. So, *is* there anything in Albert Einstein's brain that can explain why he was a genius? Several studies have attempted to argue that there is. A study was published in 2012 which suggested that there *are* aspects of Einstein's brain that are different from the average brain, such as an extra groove on his frontal lobe, the part of the brain associated with memory and planning, among other things. However, despite these physiological differences, it is unclear what exactly made Einstein so brilliant. The brains of hundreds of other geniuses would also have to be studied in order to limit potential variables. Brain shape varies from person to person, so the differences found in Einstein's brain could have just been routine variability. So far, none of the various studies published have addressed this key factor. Unfortunately, even in spite of its long afterlife, Einstein's brain has not led to any profound discoveries about what might make a person predisposed to intelligence.

https://www.pbs.org/newshour/health/the-strange-story-of-einsteins-brain

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JOURNAL ARTICLE

Brain *in the twentieth century*

W. I. MacDonald

Brain, Volume 123, Issue 1, January 2000, 3-8 Pages
https://doi.org/10.1093/brain/123.1.3
Published: 01 January 2000

Extract

When the twentieth century began, *Brain* had already achieved its majority. It was an established part of the neurological world as a reviewing and abstracting journal, as the official organ of the Neurological Society of London (the meetings of which were reported in detail) and above all as the place where neurologists from around the world placed their important work. What kind of work did they report? In this short review I shall survey the changing concerns of neurology as they are reflected in the papers published in *Brain*. With a few exceptions dictated by fairness to surviving co-authors, I have identified by name only those who are deceased.

Neurology at the end of last century was conceived as a subject which subsumed all matters to do with the nervous system, both normal and pathological, in animals and in man. Clinical neurology was firmly situated within general internal medicine. Psychiatry was assumed to be within its purview. It was taken for granted that the neurologist would be a person of broad intellectual interests. Thus the reviews covered not only what we would now consider strictly neurological matters, but philosophical and psychological ones as well. Something of the breadth and flavour of the Journal and its international standing can be gauged from a consideration of a selection from the contents of those years.

Albert Einstein - Greatest Brain of the 20th Century Documentary

Watch the Video [1:02:50]

https://www.youtube.com/watch?v=ozk-NVPYPWk

7 of Albert Einstein's Theories

https://interestingengineering.com/lists/7-of-albert-einsteins-inventions-that-changed-the-world

Prolific thinker and scientist Albert Einstein changed the world through his work.
Here we look at 7 of his most significant contributions to our understanding of the world.

- **Albert Einstein** is considered to be one of the greatest minds of the 20th century.
- His contributions to physics, such as the special and general theory of relativity, continue to exert influence today.
- But his list of achievements extends beyond just relativity and physics.

1. Quantum Theory of Light

Einstein proposed his theory of light, stating that all light is composed of tiny packets of energy called photons. He suggested that these photons were particles, but also exhibited wave-like properties, which was a revolutionary idea at the time.

Additionally, he conducted extensive research on the emission of electrons from the surface of metals when they are hit with light or a stream of photons. This laid down the foundation for his future research on the photoelectric effect, which we will discuss later in this article.

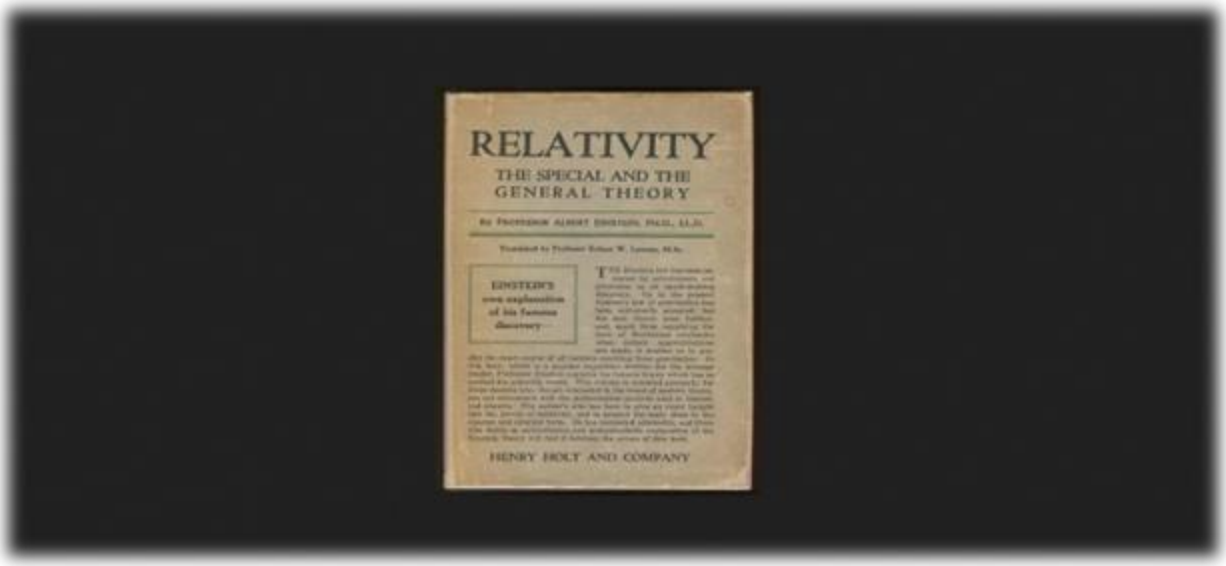
2. Special Theory of Relativity

In **Einstein's** studies, he began to notice inconsistencies in Newtonian mechanics in their relation to the understanding of electromagnetism, specifically to Maxwell's equations. In a paper published in September 1905, he proposed a new way of thinking about the mechanics of objects approaching the speed of light. This concept became known as **Einstein's** Special Theory of Relativity and it changed the understanding of physics at the time.

Einstein's revelation was that observers in relative motion experience time differently. He realized that it is possible for two events to happen simultaneously from the perspective of one observer, but occur at different times from the perspective of the other. And both observers would be right.

Understanding the Special Theory of Relativity can be a little difficult, but we'll boil it down to a simple situation.

He began with the idea that light always travels at a constant speed of 300,000 km/s, and asked what would happen to our ideas of space and time if that were the case.



Now, imagine that an observer is standing on a railway embankment as a train goes by and that each end of the train is struck by a bolt of lightning just as the train's midpoint is passing the observer. Because the lightning strikes are the same distance from the observer, their light reaches his eye at the same instant. So the observer would say the two strikes happened simultaneously.

However, there is another observer, this on the train, sitting at its exact midpoint. Because the train is moving, the light coming from the lightning in the rear has to travel farther to catch up, so it reaches this observer later than the light coming from the front. This observer would conclude the one in front actually happened first. And both observers would be correct.

Einstein determined that moving through space can also be thought of as moving through time. In essence, space and time affect each other, both being relative concepts in relation to the speed of light.

3. Brownian Motion

For anyone that has made it through a high school chemistry class, Avogadro's number might ring a bell.

Although first described by botanist Robert Brown in 1827, Brownian motion wasn't formalized until the 1900s. First by French mathematician Louis Bachelier and then by **Albert Einstein** in 1905, before he proposed his theory of relativity. Brownian motion is the erratic movement of particles in a fluid, in his paper, **Einstein** modeled the motion of pollen particles in water, providing groundbreaking evidence to support the existence of atoms ad molecules.

Additionally, the paper also described the best way to calculate Avogadro's number, which is the number of entities (atoms, molecules, ions, etc.) in one mole of a substance. His work laid down the foundation for the experimental work of Jean Perrin, who carried out experiments using a high-precision microscope to verify **Einstein's** work. He successfully calculated Avogadro's constant and definitely proved the existence of atoms — for which he received the Nobel Prize in 1926.

4. The Bose-Einstein Condensate

In 1924, **Einstein** was sent a paper by Indian physicist Satyendra Nath Bose. The paper discussed a detailed way to think of photons of light as a gas. **Einstein** generalized Bose's theory to an ideal gas of identical atoms or molecules for which the number of particles is conserved.

Einstein worked with Bose to extend this idea to atoms, which led to a prediction for a new state of matter: the Bose-Einstein Condensate. The first example of this state was produced in 1995.

He also predicted that at sufficiently low temperatures, the particles would become locked together in the lowest quantum state of the system. This phenomenon is called Bose-Einstein condensation.

A Bose-Einstein condensate is essentially a group of atoms that are cooled very close to absolute zero. When they reach that temperature, they hardly move in relation to one another. They begin to clump together and enter into exactly the same energy states. This means that, from a physical point of view, the group of atoms behaves as if they were a single atom.

We now know that this only happens for "bosons" — particles with a total spin that is an integer multiple of *h*, the Planck constant divided by 2 pi.

5. General Theory of Relativity

In 1916, **Einstein** published his G*eneral Theory of Relativity*. This paper generalizes the concepts of Special Relativity and Newton's Law of Universal Gravitation, describing gravity as a property of space and time. This theory has aided our understanding of how the large-scale structure of the universe is set up.

We know that Newton helped quantify gravity between two objects as a tugging of two bodies, independent of how massive each one is or how far apart they are. **Einstein** determined that the laws of physics hold constant for all non-accelerating observers and that the speed of light is constant no matter how fast the observer travels. He found that space and time were interwoven and that events that occur at one time for one observer could occur at a different time for the next. This led to his theory that massive objects in space could distort spacetime.

Einstein's predictions have helped modern physicists' study and understand black holes and gravitational lensing, among many other structures in the universe.

6. The Photoelectric Effect

Einstein's theory of the Photoelectric Effect discusses the emissions of electrons from metal when light shines on it, as we alluded to before. Scientists had observed this phenomenon but had been unable to reconcile the finding with Maxwell's wave theory of light.

His theory of photons aided the understanding of this phenomenon. He theorized that, when electromagnetic radiation (light) hits a metal surface, there is an emission of electrons, which he named photoelectrons.

This model forms the basis of how solar cells work — light causes atoms to release electrons, which generate a current, thus creating electricity.

7. Wave-Particle Duality

Albert Einstein's work on the development of the quantum theory was some of the most impactful work he ever accomplished. During his early career, **Einstein** persisted in asserting that light should be treated as both a wave and a particle. In other words, photons can behave as particles and as waves at the same time. This became known as the wave-particle duality.

He is quoted as saying this on the subject, "We are faced with a new kind of difficulty. We have two contradictory pictures of reality; separately, neither of them fully explains the phenomena of light, but together they do."

As we think about all of **Einstein's** work, we have to also consider how it influenced those who came after him. **Einstein's** work has influenced modern quantum mechanics, the model of physical time, the understanding of light, solar panels, and even modern chemistry. He relentlessly questioned the world around him. This is what made him great, his infinite curiosity about the world.

The important thing is not to stop questioning. "Curiosity has its own reason for existing", remarked **Einstein**. **Albert Einstein's** accomplishments have unequivocally influenced our understanding of physics as we know it today.

ABOUT THE EDITOR

Trevor English Trevor is a civil engineer (B.S.) by trade and an accomplished writer with a passion for inspiring everyone with new and exciting technologies. He is also a published children’s book author and the producer for the YouTube channel Concerning Reality.

(😊)@@@@@@@@@@@@@@@@@@@@@@@@@(😊)

Special relativity

Special relativity is a theory of the structure of spacetime. It was introduced in Einstein's 1905 paper "On the Electrodynamics of Moving Bodies" (for the contributions of many other physicists and mathematicians, see History of special relativity). Special relativity is based on two postulates which are contradictory in classical mechanics:

1. The laws of physics are the same for all observers in any inertial frame of reference relative to one another (principle of relativity).
2. The speed of light in vacuum is the same for all observers, regardless of their relative motion or of the motion of the light source.

The resultant theory copes with experiment better than classical mechanics. For instance, postulate 2 explains the results of the Michelson–Morley experiment. Moreover, the theory has many surprising and counterintuitive consequences. Some of these are:

- Relativity of simultaneity: Two events, simultaneous for one observer, may not be simultaneous for another observer if the observers are in relative motion.
- Time dilation: Moving clocks are measured to tick more slowly than an observer's "stationary" clock.
- Length contraction: Objects are measured to be shortened in the direction that they are moving with respect to the observer.
- Maximum speed is finite: No physical object, message or field line can travel faster than the speed of light in vacuum.
    - The effect of gravity can only travel through space at the speed of light, not faster or instantaneously.
- Mass–energy equivalence: $E = mc^2$, energy and mass are equivalent and transmutable.
- Relativistic mass, idea used by some researchers.

The defining feature of special relativity is the replacement of the Galilean transformations of classical mechanics by the Lorentz transformations. (See Maxwell's equations of electromagnetism.)

Some Important Web Links

https://en.wikipedia.org/wiki/Theory_of_relativity

https://www.space.com/17661-theory-general-relativity.html

https://www.space.com/15524-albert-einstein.html

https://www.amnh.org/exhibitions/einstein/energy

Albert Einstein <<>> aged 14

General relativity

General relativity is a theory of gravitation developed by Einstein in the years 1907–1915. The development of general relativity began with the equivalence principle, under which the states of accelerated motion and being at rest in a gravitational field (for example, when standing on the surface of the Earth) are physically identical. The upshot of this is that free fall is inertial motion: an object in free fall is falling because that is how objects move when there is no force being exerted on them, instead of this being due to the force of gravity as is the case in classical mechanics. This is incompatible with classical mechanics and special relativity because in those theories inertially moving objects cannot accelerate with respect to each other, but objects in free fall do so. To resolve this difficulty Einstein first proposed that spacetime is curved. Einstein discussed his idea with mathematician Marcel Grossmann and they concluded that general relativity could be formulated in the context of Riemannian geometry which had been developed in the 1800s.[10] In 1915, he devised the Einstein field equations which relate the curvature of spacetime with the mass, energy, and any momentum within it.

Some of the consequences of general relativity are:

- Gravitational time dilation: Clocks run slower in deeper gravitational wells.[11]
- Precession: Orbits precess in a way unexpected in Newton's theory of gravity. (This has been observed in the orbit of Mercury and in binary pulsars).
- Light deflection: Rays of light bend in the presence of a gravitational field.
- Frame-dragging: Rotating masses "drag along" the spacetime around them.
- Expansion of the universe: The universe is expanding, and certain components within the universe can accelerate the expansion.

Technically, general relativity is a theory of gravitation whose defining feature is its use of the Einstein field equations. The solutions of the field equations are metric tensors which define the topology of the spacetime and how objects move inertially.

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Einstein in 1882, age 3 <> Albert Einstein and Mileva Marić Einstein, 1912

Albert Einstein and Elsa Einstein, 1930

Olympia Academy founders:

Conrad Habicht, Maurice Solovine, and Einstein

List of scientific publications

https://en.wikipedia.org/wiki/List_of_scientific_publications_by_Albert_Einstein

The cited Web Link contains his Journal Articles, Book Chapters, Books and Authorised Translations

Albert Einstein (1879–1955) was a renowned theoretical physicist of the 20th century, best known for his special and general theories of relativity. He also made important contributions to statistical mechanics, especially his treatment of Brownian motion, his resolution of the paradox of specific heats, and his connection of fluctuations and dissipation. Despite his reservations about its interpretation, Einstein also made seminal contributions to quantum mechanics and, indirectly, quantum field theory, primarily through his theoretical studies of the photon.

Einstein's writings, including his scientific publications, have been digitized and released on the Internet with English translations by a consortium of the Hebrew University of Jerusalem, Princeton University Press, and the California Institute of Technology, called the Einstein Papers Project.

Einstein's scientific publications are listed below in four tables: journal articles, book chapters, books and authorized translations. Each publication is indexed in the first column by its number in the Schilpp bibliography (*Albert Einstein: Philosopher–Scientist*, pp. 694–730) and by its article number in Einstein's *Collected Papers*. Complete references for these two bibliographies may be found below in the Bibliography section. The Schilpp numbers are used for cross-referencing in the Notes (the final column of each table), since they cover a greater time period of Einstein's life at present. The English translations of titles are generally taken from the published volumes of the *Collected Papers*. For some publications, however, such official translations are not available; unofficial translations are indicated with a § superscript. Collaborative works by Einstein are highlighted in lavender, with the co-authors provided in the final column of the table.

There were also five volumes of Einstein's *Collected Papers* (volumes 1, 5, 8–10) that are devoted to his correspondence, much of which is concerned with scientific questions, but were never prepared for publication.

Chronology and major themes

Inhalt.

Vierte Folge. Band 17.

Sechstes Heft.

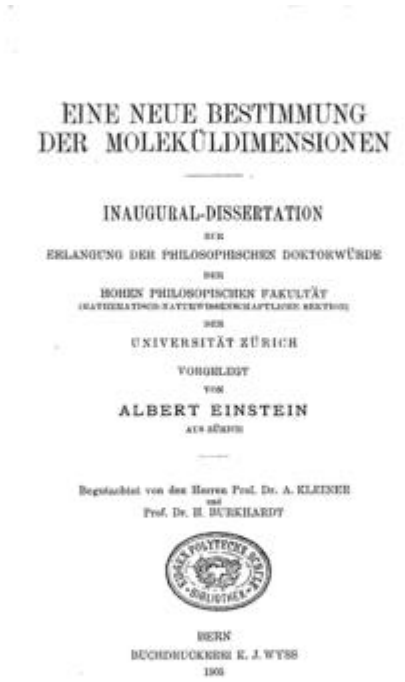
Ausgegeben am 9. Juni 1905.

Table of contents of the journal *Annalen der Physik* for the issue of June 1905. Einstein's paper on the photoelectric effect is sixth on this list.

The following chronology of Einstein's scientific discoveries provides a context for the publications listed below, and clarifies the major themes running through his work. Einstein's scientific career can be broadly divided into to periods. During the first period (from 1901 to 1933), Einstein published mainly in German-language journals, notably the *Annalen der Physik*, and, after becoming a professional physicist, worked at various German-speaking institutions in Europe, including the Prussian Academy of Sciences in Berlin. Following his permanent relocation to the United States in 1933, Einstein spent most of his time at the Institute for Advanced Study in Princeton, New Jersey, where he remained till his death in 1955. During his second period, Einstein submitted his papers in English to North American journals, such as the *Physical Review*. Einstein first gained fame among physicists for the papers he submitted in 1905, his *annus mirabilis* or miraculous year in physics. His epochal contributions during this phase of his career stemmed from a single problem, the fluctuations of a delicately suspended mirror inside a radiation cavity. It led him to examine the nature of light, the statistical mechanics of fluctuations, and the electrodynamics of moving bodies.

- From 1901 to 1904, Einstein submitted his first scientific papers, dealing with problems in thermodynamics and statistical mechanics.
- In 1905, Einstein proposed that the existence of light quanta—dubbed photons by chemist Gilbert Lewis in 1926—could explain the photoelectric effect.[7] He treated electromagnetic radiation as a gas and applied thermodynamic reasoning in his "heuristic" treatment, arguing that the energy E of a photon is given by Planck's relation, $E=h\nu$, where h is a new constant of nature (the Planck constant), and ν (nu) is

the frequency of the photon. Whereas [Max Planck] had introduced the quantum hypothesis as merely a mathematical trick to obtain the correct description of blackbody radiation (Planck's law), Einstein considered it to be an aspect of physical reality. In one of his 1905 calculations, Einstein also used, but did not justify or explain, the equation , E= pc where p is the momentum of the photon and c is the speed of light in vacuum. In 1909, Einstein showed that the photon carries momentum as well as energy and that electromagnetic radiation must have both particle-like and wave-like properties if Planck's law of blackbody radiation holds; this was a forerunner of the principle of wave–particle duality. He would go on to receive the 1921 Nobel Prize in Physics for his investigations of light quanta.


EINE NEUE BESTIMMUNG
DER MOLEKÜLDIMENSIONEN

INAUGURAL-DISSERTATION

ZUR

ERLANGUNG DER PHILOSOPHISCHEN DOKTORWÜRDE

DER

HOHEN PHILOSOPHISCHEN FAKULTÄT

DER

UNIVERSITÄT ZÜRICH

VORGELEGT

VON

ALBERT EINSTEIN

Begutachtet von den Herren Prof. Dr. A. KLEINER
und
Prof. Dr. H. BURKHARDT

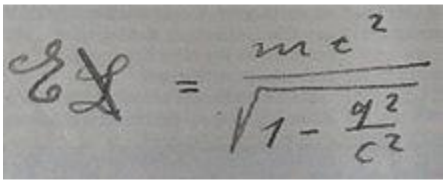
BERN
BUCHDRUCKEREI K. J. WYSS
1905

Einstein's doctoral dissertation on molecular dimensions (1905), submitted to the University of Zurich under the supervision of Alfred Kleiner

- In 1905, to avoid getting into a dispute with his supervisor, Alfred Kleiner, Einstein selected a fairly conventional problem to tackle for his doctoral dissertation, namely, the determination of molecular dimensions using classical hydrodynamics.[11] Such calculations had already been done using gases. But Einstein was the first to successfully solve the problem using liquids. Einstein obtained a respectable estimate for the Avogadro constant, after incorporating better experimental data. Einstein received his doctorate in January 1906 from the University of Zurich. Einstein's doctoral dissertation remains one of his most cited papers ever, with applications in various engineering disciplines, such as concrete mixing and dairy production. The month following this paper, Einstein submitted a theory of Brownian motion, named after botanist Robert Brown, in terms of fluctuations in the number of molecular collisions with an object, providing

further evidence that matter was composed of atoms. He showed that the distance a grain of pollen suspended in a liquid traveled from its starting point was proportional to the square root of the time elapsed and determined Avogadro's number in a new way.[8]: 103–106 A few weeks earlier, he had derived the Einstein relation for diffusion, which was the first example of the general fluctuation–dissipation theorem and gave an estimate of Avogadro's constant. Within months, Einstein's description of Brownian motion was experimentally verified by Henry Siedentopf.

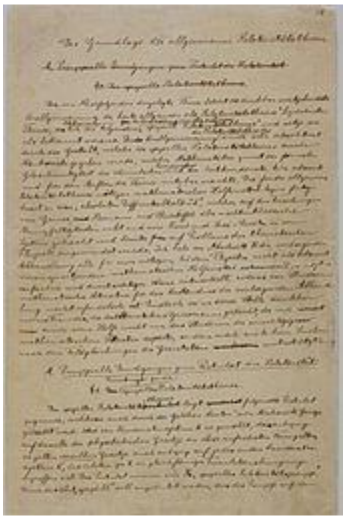
- In 1905, Einstein developed his special theory of relativity, which reconciled the Galilean relativity of motion with the observed constancy of the speed of light (a paradox of 19th-century physics). Special relativity is now considered a foundation of modern physics. Its counterintuitive predictions that moving clocks run more slowly, that moving objects are shortened in their direction of motion, and that the order of events is not absolute have been confirmed experimentally. With special relativity, Einstein rendered the notion of the luminiferous ether obsolete.



Einstein's mass–energy equation in a 1912 manuscript. He originally used L to represent energy instead of E, and V instead of c for the speed of light.

- In 1905, Einstein concluded that "The mass of a body is a measure of its energy content." In modern form, the equation he wrote down was , $E = mc^2$ where E is of an object, m is the mass of that object, and c is the speed of light in vacuum. He suggested that "bodies whose energy contents is variable to a high degree, e.g. salts of radium" be used to test his new equation. Einstein's mass–energy equivalence was later verified by studying mass defect in atomic nuclei. The energy released in nuclear reactions—which is essential for nuclear power and nuclear weapons—can be estimated from such mass defects.
- In 1907 and again in 1911, Einstein developed the first quantum theory of specific heats of a solid by generalizing Planck's relation. His theory resolved a paradox of 19th-century physics that specific heats were often smaller than could be explained by any classical theory. His work was also the first to show that Planck's relation, $E = h\nu$, was a fundamental law of physics, and not merely special to blackbody radiation.

- Between 1907 and 1916, Einstein developed the general theory of relativity, a classical field theory of gravitation that provides the cornerstone for modern astrophysics and cosmology. General relativity, which has passed all experimental tests to-date, makes a number of surprising predictions, such as the bending of light by gravity, that matter affects the flow of time, the stretching or redshift of light due to gravity, and frame dragging. While Einstein was highly skeptical that black holes could exist, publishing a paper in 1939 explaining his view, evidence accumulated since the 1960s thanks to advances in observational astronomy, such as radio telescopes, suggests that they do. Furthermore, the principle of the equivalence of inertial and gravitational mass, the foundation of general relativity, has also survived all tests ever devised.
-
- Between 1914 and 1915, Einstein and Wander Johannes de Haas published a series papers on their experiments showing that a change in the magnetic moment of a free body caused this body to rotate. The Einstein-de Haas effect is a consequence of the conservation of angular momentum and is a demonstration of quantum spin, not yet understood at the time. Einstein and de Haas argued that their results supported the hypothesis by André-Marie Ampère that "molecular currents" were responsible for the field of a magnet, essentially suggesting the existence of the electron.



First page from Einstein's manuscript explaining general relativity (from 1915-16)

- In 1916, Einstein predicted the existence of gravitational waves. However, this paper was full of errors and misconceptions. He corrected most of these in another paper published in 1918, but his formula for the energy flux radiated by a slow-moving source was still off by a factor of two. Arthur Stanley Eddington later noticed and corrected the error. Einstein returned to the problem in 1936 with his assistant, Nathan Rosen, arguing that gravitational waves did not exist. An anonymous reviewer commented that they had misunderstood the nature of the coordinates they were

using.[4] Einstein and Rosen resolved his issue and reached the opposite conclusion, exhibiting an exact solution to the Einstein field equations, the Einstein–Rosen metric, describing cylindrical gravitational waves.[4][41] Gravitational waves have been detected by observing the Hulse–Taylor pulsar and directly by the Laser Interferometer Gravitational-wave Observatory (LIGO).

-
- In 1917, Einstein presented the semi-classical Einstein–Brillouin–Keller method for computing the eigenvalues of a quantum-mechanical system. An improvement of the Bohr–Sommerfeld quantization condition, it allows for the solution of a variety of problems. The Bohr model of the hydrogen atom is a simple example, but the EBK method also gives accurate predictions for more complicated systems, such as the dinuclear cations H_2^+ and HeH^{2+}.
- In 1917, Einstein began the scientific study of cosmology. In order to ensure that his field equations predict a static universe, as was commonly thought at the time, Einstein introduced the cosmological constant (capital lambda). In the early 1930s, upon learning of Edwin Hubble's confirmation of the expansion of the universe, Einstein retracted .The current understanding is that is non-zero. As Steven Weinberg explained, "it was not easy to just drop the cosmological constant, because anything that contributes to the energy density of the vacuum acts just like a cosmological constant."
-
- In 1918, Einstein developed a general theory of the process by which atoms emit and absorb electromagnetic radiation (the Einstein coefficients), which is the basis of lasers (light amplification by stimulated emission of radiation) and shaped the development of modern quantum electrodynamics, the best-validated physical theory at present.
-
- In 1924, Einstein read a paper from Satyendra Nath Bose deriving Planck's law using a new statistical method for photons. He developed the idea further into the Bose–Einstein statistics and applied it to ensembles of particles with mass, such as atoms, and predicted the Bose–Einstein condensates, a new state of matter. The Bose–Einstein condensation was first achieved in 1995 by Carl Edwin Wieman and Eric Allin Cornell using rubidium-87. Since then, the Bose–Einstein condensation has also been achieved using other materials, such as liquid helium-4, which becomes a superfluid at temperatures below 2.17 K. Bose and Einstein's papers are seminal contributions to quantum statistical mechanics, which form the basis for superfluidity, superconductivity, and other phenomena.
-
- In 1935, together with Boris Podolsky and Nathan Rosen, Einstein put forward what is now known as the EPR paradox. Einstein and his colleagues argued that the quantum-mechanical wave function must be an incomplete

description of the physical world, and that there could be "hidden variables" not accounted for in standard quantum mechanics. This paper describes the phenomenon of quantum entanglement, a term coined by Erwin Schrödinger in a paper published in the same year in which Schrodinger states his cat paradox. It is Einstein's most controversial paper, and the most important one he published after migrating to the U.S. In 1951, David Bohm reformulated he original thought experiment was reformulated in terms of spin and in 1964, John Stewart Bell proposed experiments to test the inequalities he derived. Experiments conducted since the 1980s have demonstrated the reality of quantum entanglement and disproven Einstein's notion of local realism.

- In 1935, Einstein and Rosen proposed the Einstein–Rosen bridge, a hypothetical tunnel connecting different regions of the same universe, in order to resolve the difficulties associated with singularities, such as the ones in the Schwarzschild solution, the central singularity and the one on the surface of the black hole (the event horizon). However, subsequent research demonstrated that the event horizon was a coordinate singularity, not a physical one. (It can be removed by the Eddington–Finkelstein coordinates or the Kruskal–Szekeres coordinates.) Moreover, John Archibald Wheeler and Robert Works Fuller showed in 1962 that this hypothetical structure, also known as a wormhole, was unstable and would collapse before even photons could pass through. Today, the wormhole remains a plot device in science fiction for space and time travel.

- In the final thirty years of his life, Einstein explored whether various classical unified field theories could account for both electromagnetism and gravitation and, possibly, quantum mechanics using increasingly sophisticated mathematics, such as distant parallelism. He was joined by a handful of researchers, notably Hermann Weyl, Theodor Kaluza, and Oskar Klein. However, their efforts were ultimately unsuccessful, since those theories did not match experimental results. For example, the Kaluza–Klein theory, which Einstein briefly pursued, predicted the wrong mass for the electron by a factor of about 10^{18}.

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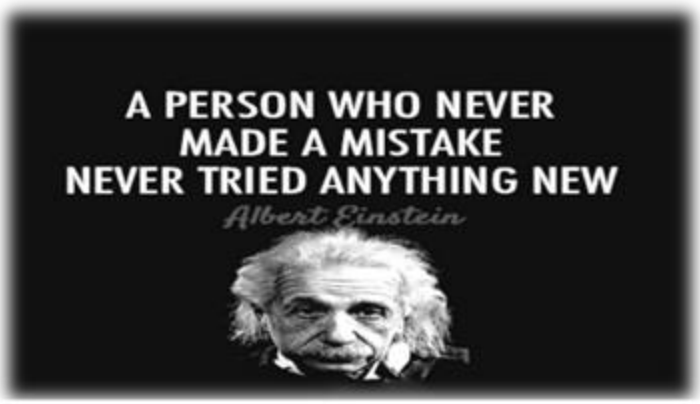
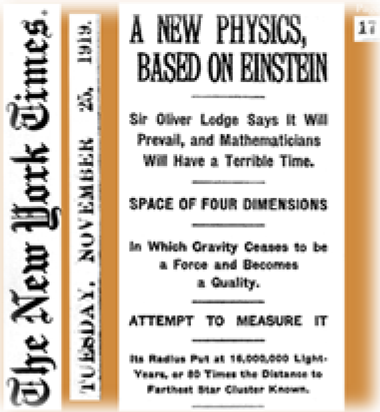




The New York Times.

TUESDAY, NOVEMBER 25, 1919.

A NEW PHYSICS, BASED ON EINSTEIN

Sir Oliver Lodge Says It Will Prevail, and Mathematicians Will Have a Terrible Time.

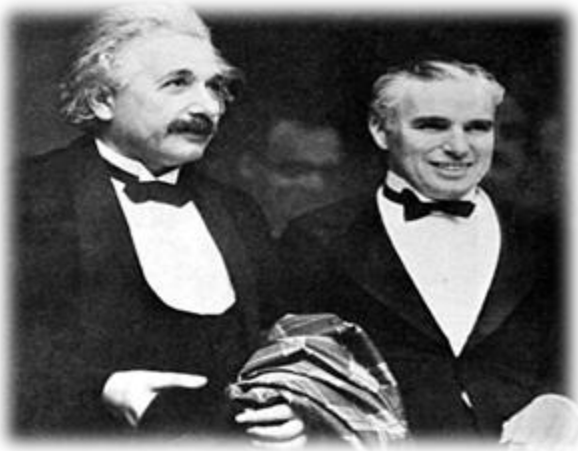
SPACE OF FOUR DIMENSIONS

In Which Gravity Ceases to be a Force and Becomes a Quality.

ATTEMPT TO MEASURE IT

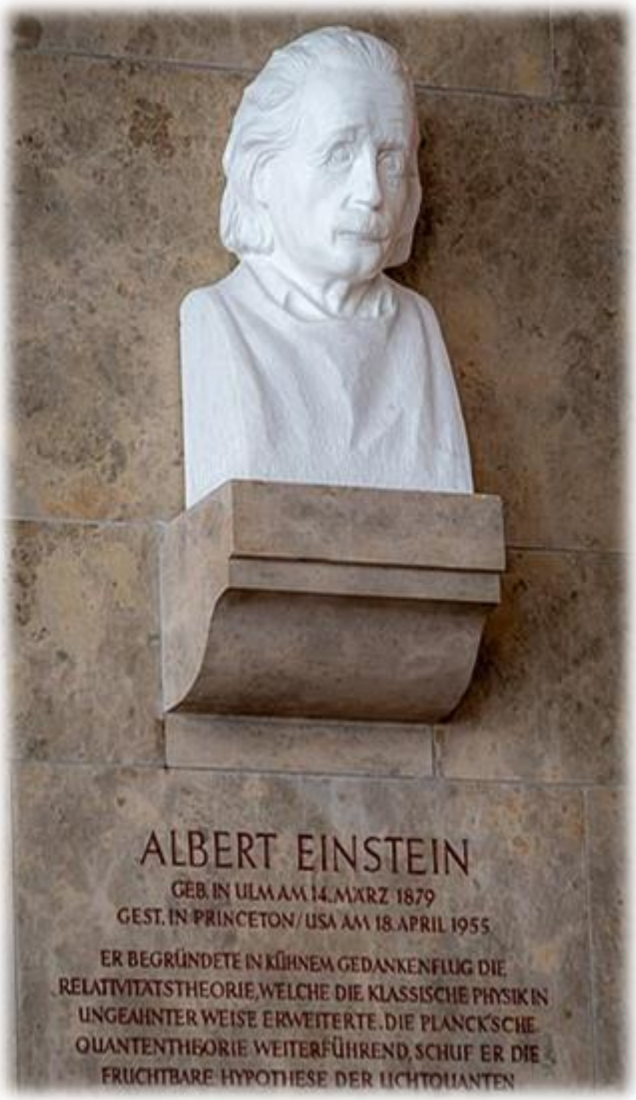
The New York Times reported confirmation of the bending of light by gravitation after observations (made in <u>Príncipe</u> and <u>Sobral</u>) of the 29 May 1919 eclipse were presented to a joint meeting in London of the <u>Royal Society</u> and the <u>Royal Astronomical Society</u> on 6 November 1919.

Einstein at a session of the International Committee on Intellectual Cooperation (League of Nations) of which he was a member from 1922 to 1932.



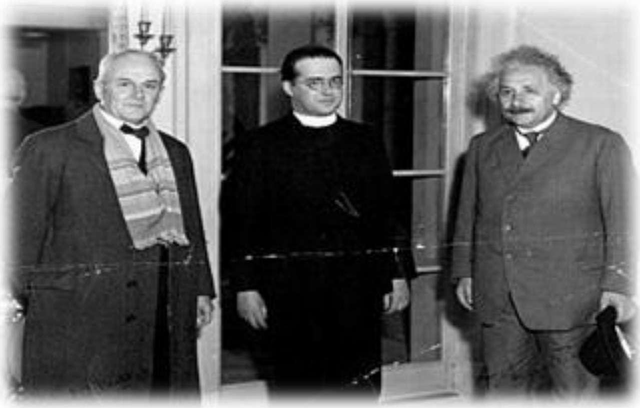
Einstein with Charlie Chaplin at the Hollywood premiere of Chaplin's City Lights, January 1931

Winston Churchill and Einstein at Chartwell House, 31 May 1933

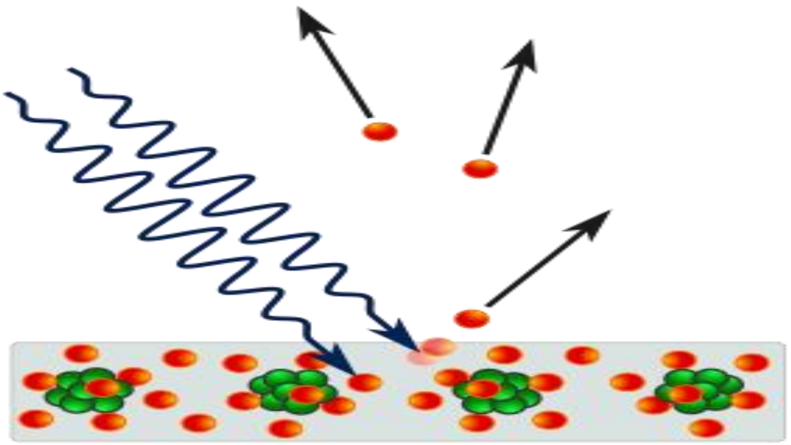


Marble bust of Einstein at the Deutsches Museum in Munich

Einstein accepting a US citizenship certificate from judge Phillip Forman



Robert A. Millikan, Georges Lemaître and Einstein at the California Institute of Technology in January 1933



The photoelectric effect. Incoming photons on the left strike a metal plate (bottom), and eject electrons, depicted as flying off to the right.

The 1927 Solvay Conference in Brussels, a gathering of the world's top physicists. Einstein is in the center.

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The Albert Einstein® Archives
The Hebrew University of Jerusalem
The Library Authority

http://www.albert-einstein.org/

100 years after Einstein's visit in the Land of Israel:

A. Einstein
(1879-1955)

Dear visitor,

We are excited to announce that a newly designed platform will be launched in the near future at www.alberteinstein.info, serving as a comprehensive portal for all things related to Albert Einstein. A beta version is already available for your peruse at albert.dooble.us.

The catalog is operated in partnership with the Einstein Papers Project (EPP), and in collaboration with Princeton University Press, the publisher of the Collected Papers of Albert Einstein. For more information about our ongoing close partnership, please visit our EPP page.

The Collected Papers of Albert Einstein are currently available online at Digital Einstein Papers. This initiative, launched by EPP in collaboration with the Hebrew University, Princeton University Press, the California Institute of Technology, and the Tizra publishing platform in 2014, offers free public access to the published volumes of Einstein's works.

We have now finished an extensive project that will make Einstein's scientific notations, many of which were never published, available to the public by searching strings of LaTeX code of the notations. This is a novel approach to searching scientific content in databases that has never been implemented before. You can give it a try at the beta website's search interface. Enter a LaTeX code in the First Line field and surprise yourself with the result's list.

Please note that while not all images are viewable directly due to contractual constraints, you can request them via email.

The Albert Einstein Archives Team

Last Modified:
September 24, 2024

ATOMIC HERITAGE FOUNDATION

https://ahf.nuclearmuseum.org/ahf/profile/albert-einstein/

Albert Einstein (1879-1955) was a German-born theoretical physicist and winner of the 1921 Nobel Prize in Physics.

Einstein influenced the beginning of the Manhattan Project. In collaboration with Leo Szilard, Einstein wrote a letter to President Roosevelt in 1939, warning of possible German nuclear weapons research and proposing that the United States begin its own research into atomic energy.

Einstein played no role in the Manhattan Project, having been denied a security clearance in July 1940 due to his pacifist tendencies. After World War II, he worked to control nuclear proliferation. He later regretted signing the letter to Roosevelt, saying in a Newsweek interview that "had I known that the Germans would not succeed in developing an atomic bomb, I would have done nothing."

Scientific Contributions

In 1896, Einstein began studying to be a physics and mathematics teacher at the Swiss Federal Polytechnic School in Zurich. He graduated in 1901, the same year he became a citizen of Switzerland. He then worked at the Swiss Patent Office. Einstein earned his Ph.D. from the University of Zurich during his "miracle year," 1905, where he published four groundbreaking papers and won notice from academics.

Einstein's special theory of relativity sought to harmonize the laws of mechanics and laws of the electromagnetic field. His investigations also helped establish the photon theory of light. Based on the special theory of relativity, he proposed a theory of gravitation, and in 1916 he published his paper on the general theory of relativity. In 1921, he was awarded the Nobel Prize in Physics "for his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect." For more on Einstein's scientific contributions, visit the Nobel Prize website.

Later Years

As the Nazis rose to power in Germany, Einstein left for the United States and accepted a position at the Institute for Advanced Study in Princeton, NJ in 1933. Einstein became an American citizen in 1940. Einstein turned down an offer to serve as President of Israel, and was a co-founder of the Hebrew University of Jerusalem. He died on April 18, 1955.

Albert Einstein's Timeline

1879 Mar 14th Born at Ulm, in Württemberg, Germany.

1896 Entered the Swiss Federal Polytechnic School in Zurich to be trained as a teacher in physics and mathematics.
1901 Received his diploma, acquired Swiss citizenship, and accepted a position as technical assistant in the Swiss Patent Office.
1905 Received his Ph.D. from the University of Zurich.
1905 Einstein's annus mirabilis (miracle year): published four groundbreaking papers on the photoelectric effect, Brownian motion, special relativity, and the equivalence of mass and energy.
19141932 Directed the Kaiser Wilhelm Institute for Physics in Germany.
1921 Received the Nobel Prize in Physics.
1933 Renounced his German citizenship and emigrated to America.
19331955 Worked at the Institute for Advanced Study at Princeton, New Jersey.
1939 Wrote letter to President Roosevelt warning of German nuclear weapon goals and recommending that the US become involved in such research;
1940 Became a US citizen.
1955 Apr 18th Died in Princeton, New Jersey.

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Case Files

Albert Einstein

https://fi.edu/en/news/case-files-albert-einstein

Introduction

Though he described himself as a "mathematical ignoramus," Albert Einstein's thinking was so complex that accomplished members of the scientific community still struggle to wrap their minds around the meaning and implications of his theories. Born in Germany in 1879, the frizzy-haired physicist conducted some of his most important research in Princeton, New Jersey, where he spent the later years of his life. Perhaps best known for his Theory of Relativity and his equation E=mc2, Einstein's work revolutionized the field of theoretical physics and made him a celebrity throughout the globe.

As he presented Einstein at Medal Day exercises, Dr. Frederick Palmer, Jr. of The Franklin Institute's Committee on Science and the Arts said: *"The romance of his achievement has been such that mathematical physics has become popular with the public."*

Who was Albert Einstein? What were his achievements in the field of physics?

The Nature of a Genius

Before he was known as a genius whose work profoundly changed the way the world thinks about physics, Albert Einstein thought of himself as "merely curious." In his youth, his curiosity led him to explore the field of natural science through private reading outside

of his high school classes, and to apply his knowledge to his own thoughts and questions about the nature of the cosmos.

Einstein was a philosopher and a human rights activist as well as a scientist. During his lifetime he witnessed two world wars and predicted the invention of the atomic bomb in a now-famous letter to President Franklin Delano Roosevelt. Einstein eloquently recorded his thoughts on religion, science and human rights, and the pages of his writings are imbued with the complex emotions and musings of a man who witnessed profound changes in the world around him, and whose direct involvement in major scientific breakthroughs inspired him to think about the extent to which developments in science effect society at large.

Despite the fame brought to him by his theories and research, Einstein's sense of humility remained intact. Though anecdotal episodes from his youth show some signs of arrogance and frustration with his fame, his adulthood is marked by a mature gratitude for his abilities and a resigned acceptance of his celebrity status. Reflecting on his success in his later years Einstein wrote, "For the most part I do the thing which my own nature drives me to do. It is embarrassing to earn so much respect and love for it."

The "Lone Traveler" Sets Out

Albert began his schooling in Germany, where his teachers disciplined him and his classmates were disrespectful to the young Einstein. His primary school classes emphasized memorization and learning by rote. Albert was reprimanded by his German elementary school teachers for thinking too much about the meaning of their questions and failing to produce responses as quickly as his peers. At home, Albert obediently completed his homework before engaging in solitary games. One of his favorite pastimes as a child was constructing houses of cards, which sometimes was able to reach four stories. Even as a young child Einstein valued solitude, and in 1930 he would reflect: "I am truly a 'lone traveler' and have never belonged to my country, my home, my friends, and even my immediate family with my whole heart; in the face of all these ties, I have never lost a sense of distance and a need for solitude—feelings which increase with the years" (qtd in Cassidy 64).

Working Ahead

In the fall of 1888, when Einstein was nine years old, he entered a secondary school in Munich, Germany called the Luitpold-Gymnasium. This school emphasized non-scientific subjects like Latin and ancient Greek. While he did earn good grades in his classes, they did not spark his interest. It was during these secondary school days that Albert began to

diverge from the curriculum prescribed for him, engaging in his own private reading. At age thirteen he asked his parents to purchase the mathematics textbook that he would be using the following year, and proceeded to work his way through the entire mathematics program at the Lutipold-Gymnasium in a matter of months. He indulged his passion for physics and physical phenomena by reading textbooks that were, at the time, key writings on the natural sciences.

In Need of a Liberal Arts Education

As his thoughts shifted towards college and more advanced studies, Albert was determined to apply to the Federal Institute of Technology (FIT) in Zurich, Switzerland. He disliked the Lutipold-Gymnasium and did not complete his studies there. He instead committed himself to a period of self-study, during which he acquired knowledge of theoretical physics. He took the FIT's competitive entrance exam at age sixteen, more than a year younger than the other students who sat for the exam at the same time. The results of his exam revealed that he had done well on the mathematical-physical section of the test, while he had failed the general portion of the exam which tested his knowledge of literary and political history and of foreign language. Albert was thus required to attend a secondary school in the nearby Swiss town of Aarau before he was admitted to the FIT.

Einstein began his studies at the Federal Institute of Technology (FIT) in October of 1896. As a college student he often skipped lectures and studied for tests by borrowing notes from his classmates, and would later describe himself as a mediocre university student. While not an avid participant in his classes, Albert's genuine interest in theoretical physics inspired him to devote large periods of time to its study. He participated in a number of physics experiments while a student, and consistently strove to unite the abstract concepts of theoretical physics with practical matters. His doctoral thesis made strides towards such unification, combining the theoretical claim for the existence of molecules with a description of the physical law governing the behavior of molecules. Einstein used experimental data to further describe this law and to further develop the relationship between the theoretical and the practical.

Princeton Days

After he completed his degree at the FIT, Einstein found work as an assistant professor and eventually as a full professor of theoretical physics. He preferred researching to teaching, and in 1914 he accepted a paid research position in Berlin, Germany, which was considered the "capital city" of physics at that point in time. In 1933 the rise of Nazi power in Germany prompted Einstein to resign from his position in Berlin and flee to the United States, where he took up residence at 112 Mercer Street in Princeton, New Jersey and assumed a position on the faculty of Princeton's Institute for Advanced Study.

Oswald Veblen, the first professor in the Institute for Advanced Study, helped select and relocate Einstein and other foreign mathematicians after Hitler's rise to power in Europe. Veblen was a leading geometer and served a term as president of the American Mathematical Society and of the International Congress of Mathematicians, held at Harvard. Though highly respected as a scholar, Veblen valued his relationships with his students and helped design common spaces in Princeton buildings in order to help encourage the formation of student-faculty relationships.

The verification and publication of Einstein's Theory of Relativity in 1919 brought him instant celebrity status.

Under Investigation

In August of 1939 Einstein mailed a letter to the White House, informing President Franklin Delano Roosevelt of the potential threat posed by the discovery of and subsequent experimentation with nuclear fission in Berlin, Germany. His ominous prediction read:

"This new phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain—that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory."

History indicates that Einstein sent four letters to President Roosevelt, each expressing an increased urgency for action. In December of 1941, Roosevelt heeded Einstein's warning and convened the American investigation into nuclear fission and the development of such a bomb known as the Manhattan Project. This top-secret project went underway in a laboratory in Los Alamos, New Mexico. Four years later, in 1945, the United States dropped the newly-developed atomic bomb, devastating the Japanese cities of Hiroshima and Nagasaki.

Despite his role in alerting the President to the possibility of nuclear weapons, Einstein did not participate in the Manhattan Project. Though he was granted American citizenship in 1940, his involvement with liberal organizations whose missions called for world peace made Einstein a "radical" in the eyes of the Federal Bureau of Investigation. In response to the perceived threat posed by Einstein, the FBI compiled an extensive secret file on the scientist, monitoring and recording his movements. His status as a security threat prevented Einstein from gaining the security clearance necessary to enter the secret laboratory in New Mexico. It is very likely that this was not a source of disappointment for Einstein, who publicly declared his dedication to pacifism. He was quite distressed when the public mind associated him with the dropping of the atomic bombs in 1945 and the subsequent civilian casualties.

Personal Commitments

Einstein committed to his family, and throughout the course of his life he married twice and had three children. All three children were a product of his relationship with Mileva Maric, whom he encountered while he was a university student. Mileva was a classmate and a fellow scientist, and evidence suggests that she was instrumental in the development of some of her husband's theories. Einstein's children were named Lieserl, Hans Albert and Eduard, who was known as "Tete." Einstein eventually divorced Mileva, marrying his cousin Else Löwenthal four months later.

Einstein was also deeply committed to his Jewish faith. His religious beliefs inspired him to grapple with philosophical thoughts and to champion the cause of Zionists and their quest for a Jewish home state in Palestine. He was offered the presidency of Israel in 1952, though he declined this honor. He died three years later of an aneurysm of the abdominal aorta, bequeathing much of his writings and photographs to the Hebrew University of Jerusalem.

An Eternal Riddle

Though he is conceived of as a genius in modern society, Einstein's ways of thinking diverged sharply from those of a majority of other scientists when he initially penned some of his most famous theories. In the early years of the 20th Century, theorists were not regarded with great respect, but Einstein viewed theoretical work as a high calling. Contemplating theoretical physics, Einstein wrote, "I soon learned to scent out that which was able to lead to fundamentals and to turn aside from everything else, from the multitude of things which clutter up the mind and divert it from the essential...Out yonder there is this huge world, which exists independently of us human beings and which stands before us like a great, eternal riddle."

Electromagnetic Waves

Some scientists in the late 1800s and early 1900s believed in and described an entity known as "the ether." The ether was thought to be a backdrop at a state of absolute rest against which the movement of elements of the cosmos occurred. Einstein disagreed with the existence of the ether, which will be seen during the discussion of his theory of special relativity. However, an understanding of the ether is important for understanding the theory of electromagnetic phenomena which preceded Einstein's theory of relativity.

During the 19th Century, scientists Michael Farady, James Clerk Maxwell and Heinrich Hertz formulated a theory that described electromagnetic phenomena. This theory

indicated that electric and magnetic forces resulted from the effect of electric and magnetic fields existing in space between electric charges. These electric charges were produced by the ether, which was thought to be able to exert electric forces on ordinary matter. Hertz showed that moving electromagnetic fields could break away from ordinary matter and propagate through the ether as independent electromagnetic waves carrying energy. These electromagnetic waves come in both visible and invisible forms. Hertz showed that visible light is one visible form of the electromagnetic wave. Invisible electromagnetic waves include radio waves, x-rays and microwaves. The concept of such waves moving through the ether can be likened to the waves that spread over a pond after a stone is thrown into the water. The ripples in the pond can be thought of as the equivalent of electromagnetic waves, and the still water as the equivalent of the ether. In a pond, the force of the stone hitting the water results in the ripples. One of the things puzzling the scientists of Einstein's time was what exactly caused the formation of electromagnetic fields whose independent movement resulted in the electromagnetic waves which they conceived of as moving through space.

The Electron

In 1897, the source of electromagnetic fields was discovered: the electron. At the time of its discovery, the electron possessed the smallest mass known. It also carried the smallest electric charge known. Because of its charge, it was found to be the source of electromagnetic fields. However, the electron posed a problem for scientists grappling with electromagnetic theory. As is discussed above, electromagnetic theory dealt with fields and waves, entities that were thought to be continuous and without mass. Electrons are neither continuous nor without mass: they are individual, charged particles that have mass. Electrons thus did not "fit into" electromagnetic theory as it was understood in the late 19th Century. They posed yet another riddle for Einstein and his contemporaries.

A Quantum Leap

In 1905, Einstein challenged the concept that visible light, one form of the electromagnetic wave, always behaved as a continuous wave. Einstein argued that in certain cases light behaves as individual particles. He called these particles "light quanta," and said that each "light quanta" carries a "quantum," meaning a fixed quantity of energy. A light beam is thus composed of many "light quanta" which are observed as one continuous wave. The total energy of a light beam, Einstein said, is the sum total of the individual energies of the distinct "light quanta." Today, these "light quanta" are called "photons." Theories that treat total energy as "quantized" (meaning that total energy is calculated by adding together the fixed energies of the individual "quanta" of which the overall energy is composed) are known as quantum theories.

It's (Photo) Electric!

Einstein's light quantum hypothesis helped to explain certain visible light behavior which could not be explained if visible light were understood to exist in the form of a wave, rather than in the form of tiny individual particles. One of these phenomena was known as the photoelectric effect. Scientists had observed that, when light hit metal, electrons were ejected from the surface of the metal. Einstein's light quanta could eject electrons from the surface of the metal by changing the energy states of the electrons they hit. Light quanta are little bundles of energy, and according to electron theory, electrons absorb energy. The act of absorbing energy takes an electron to a higher energy state, causing it to jump. When it returns to its state of rest, it emits the energy it has absorbed in the form of light. This results in the observable ejection of electrons from the metal's surface known as the photoelectric effect.

Galileo and Relativity

Though Einstein is the scientist most frequently associated with the theory of relativity, there are several thinkers who are responsible for its formulation. The first known person to theorize about relativity was Galileo, who articulated the first "relativity principle" in the seventeenth century. In generating his relativity principle, Galileo removed the distinction between stationary and moving observers, arguing that people on earth cannot tell if they are really at rest or if they are moving with the rotation of the earth each day. To demonstrate this, Galileo used the example of a cannonball falling from the top of a ship's mast. He noted that the cannonball will land at the base of the mast whether the ship is moving steadily through the ocean, or whether it is at rest in a dock. Even if they observe the falling ball, people on the ship cannot tell if they are really at rest or if they are moving with the ship. They cannot distinguish their state of rest from the ship's state by observing motion that takes place within the "reference frame" of the ship. In other words, a person at rest on the deck of a ship cannot determine whether the ship is at rest or moving at a steady speed through the ocean by observing actions that happen on the ship itself. That person must observe the ship relative to its surrounding environment in order to make such a determination.

A Matter of Principle

In 1905, Einstein wrote a paper entitled, "On the Electrodynamics of Moving Bodies." This paper served as the foundation for his theory of relativity. It also included many of the theories and results of scientists whose work had preceded Einstein, so much so that many of his contemporaries had a difficult time distinguishing Einstein's "theory of special relativity" from other accepted theories of the time. The main difference between Einstein's theories and other prevalent scientific theories of the 1900s lies in how Einstein went about

deriving his theories. While many of his contemporaries drew "constructive theories," Einstein drew "principle theories."

Einstein's theories were not hypotheses built on data reached through experimentation. Rather, they were universal principles intended to impact all of physics. Throughout his life, Einstein was driven by a desire to isolate a single theory that would unify gravitation and electromagnetic fields. Though this single theory has not yet been found, Einstein's work has inspired physicists of today to continue the search for a unified theory.

Special Relativity

Einstein's theory of special relativity is fundamentally a theory of measurement. He qualified the theory as "special" because it refers only to uniform velocities (meaning to objects either at rest or moving at a constant speed). In formulating his theory, Einstein dismissed the concept of the "ether," and with it the "idea of absolute rest." Prior to the generation of Einstein's theory of special relativity, physicists had understood motion to occur against a backdrop of absolute rest (the "ether"), with this backdrop acting as a reference point for all motion. In dismissing the concept of this backdrop, Einstein called for a reconsideration of all motion. According to his theory, all motion is relative and every concept that incorporates space and time must be considered in relative terms. This means that there is no constant point of reference against which to measure motion. Measurement of motion is never absolute, but relative to a given position in space and time. Returning to Galileo's cannonball, Einstein considered this: the cannonball falling from the mast of the ship would appear to an observer standing on the deck of that ship as though it dropped straight down; however, to an observer standing on the shore, the cannonball would appear to follow a curved trajectory on its way to the base of the mast. Which trajectory did the ball actually follow? According to Einstein's theory of special relativity, the answer is, both—and neither. Each observer's observation is valid in its own reference frame, yet each is no more than an artifact of the measurement, or observation, undertaken by the observer.

Implications of Relativity

Einstein's theory of special relativity has many complex consequences, which confuse even scientists of the present. One of the most famous consequences of this theory is the formula $E=mc^2$. This theory relates energy to mass times the square of the speed of light. Often considered the "speed limit" of the universe, the speed of light is equivalent to about 186,000 miles per second.

Four-Dimensional Space

In 1904, mathematician Hermann Minowski succeeded in representing Einstein's theory of special relativity mathematically. He did so by introducing the concept of four dimensions: three of space and one of time. Using his mathematical representation, he was able to describe the positions and motions of objects such as speeding electrons as they moved through space. Minowski's four-dimensional space-time helped Einstein to develop his theory of general relativity, which he would come to regard as his greatest achievement.

Principle of Equivalence

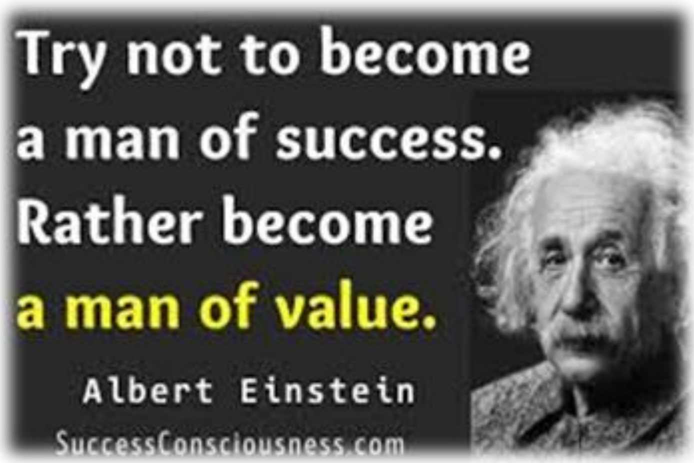
Special relativity applies only to cases in which objects are moving at a uniform velocity. General relativity, however, is applicable to all forms of accelerated motion. This theory of general relativity arose from Einstein's principle of equivalence. Einstein formulated this principle by examining a given mass in two different states. The first state occurs when the mass in question is acted on by gravity, and the second when the mass is in a state of inertia (when it resists forces and accelerations). According to Einstein's principle of equivalence, the given mass is equivalent in both states. Take, for example, a spinning top. According to the principle of equivalence, the top has the same mass whether it is falling off a desk (being acted on by gravity) or whether it is spinning atop a desk (in a state of inertia). This principle may seem obvious, and in fact people since Newton's time had simply assumed it to be true. However, the implications of the principle of equivalence are far from obvious, and Einstein was the first to realize those implications.

General Relativity

Einstein's theory of general relativity unites his theory of special relativity with the concept of gravity conceived of by Sir Isaac Newton. Einstein's key insight was that gravitation is not the result of a force. It is rather a manifestation of curved space and time. Einstein's theory of general relativity can be understood by considering the following scenario. An astronaut sitting in a space capsule waiting to launch at Cape Canaveral feels his normal weight. While in space, free from gravitational pull, the astronaut feels weightless. However, if the space capsule were to accelerate upwards in space at exactly the acceleration of gravity back on earth, the astronaut would be pushed into his seat with a force exactly equivalent to his own weight. The astronaut would be unable to distinguish between the sensation of sitting in the space capsule prior to launch in Cape Canaveral, and the sensation of sitting in the space capsule as it accelerates upwards in space at exactly the acceleration of gravity. He could only distinguish between the two by looking out the window.

Curved Space

Einstein's theory of general relativity describes space as curved, with the "curved space" being the four-dimensional space-time conceived of by Minowski. The curvature of space results in the effects of gravity. This notion of curved space becomes more tangible by thinking again about the astronaut and the space capsule, but this time introducing a beam of light into the capsule. If a beam of light is shone from the top of one capsule wall to the opposite wall while the capsule is accelerating upwards in space, the light will appear curved. This is because, in the time it takes for the light beam to move across the cabin to the opposite wall, the cabin will have accelerated upwards and the beam will appear to curve across the cabin and hit below the spot directly across from where it started. The light will also appear to curve across the top of the space capsule if the capsule is at rest in Cape Canaveral. In other words, the light beam acts as if it is being pulled down by gravity. The space-time through which it moves can be understood to be curved by the presence of a massive body: in this case, the earth. In space, the curvature of space itself causes all objects, such as light or planets or spaceships, to follow the curvature. In both cases, the gravitational effect occurs because of the curvature of space.



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